March 6, 1884.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

In pursuance of the Statutes, the names of Candidates for election into the Society were read from the Chair, as follows:—

Allman, Professor George Johnston, LL.D.
Atkinson, Professor Edmund, Ph.D.
Bagot, Alan, C.E.
Baird, A. W., Major R.E.
Balfour, Professor Isaac Bayley, D.Sc.
Baxendell, Joseph, F.R.A.S.
Bell, James, F.I.C.
Bidwell, Shelford, M.A.
Blake, Rev. Professor J. F., M.A.
Browne, Walter Raleigh, M.A.
Burdett, Henry Charles, F.L.S.
Buzzard, Thomas, M.D.
Claudet, Frederic, F.C.S.
Carpenter, Philip Herbert, D.Sc.
Colenso, William, F.L.S.
Conroy, Sir John, Bart., M.A., F.C.S.
Creak, Ettrick William, Staff Commander R.N.
Cunningham, Allan Joseph Champneys, Major R.E.
Curtis, Arthur Hill, D.Sc.
Forbes, Professor George, M.A.
Goodeve, Professor Thomas Minchin, M.A.
Green, Professor A. H., M.A.
Hartley, Professor Walter Noel, F.R.S.E.
Herschel, Professor Alexander Stewart, M.A.
Hicks, Henry, M.D.
Hicks, Professor William M., M.A.
Hudleston, Wilfrid H., M.A.
Japp, F. R., Ph.D.
Kent, William Saville.
Laughton, John Knox, M.A.
Lamb, Professor Horace, M.A.
Lewis, J. R., M.B.
Lyster, George Fosbery, M.I.C.E.
MacGillivray, Paul Howard, M.A.
McKendrick, Professor John G., M.D.
Manson, Patrick, M.D.
Marshall, Professor A. Milnes, M.D.
Meldola, Raphael, F.R.A.S.
Miller, Francis Bowyer, F.C.S.
Milne, Professor John, F.G.S.
Nobel, Alfred.
Ord, William Miller, M.D.
O'Sullivan, Cornelius.
Pattison, Samuel Rowles, F.G.S.
Perry, Professor John.
Pritchard, Urban, M.D.
Pye-Smith, Philip H., M.D.
Ransome, Arthur, M.D.
Rawlinson, Sir Robert, C.B., M.I.C.E.
Rendel, George Wightwick.

Rodwell, George F., F.R.A.S.
Roy, Prof. Charles Smart, M.D.
Rücker, Professor Arthur William, M.A.
Smith, Willoughby.
Spiller, John, F.C.S.
Stotherd, Richard Hugh, Colonel R.E.
Tate, Professor Ralph, F.G.S.
Tenison-Woods, Rev. Julian E., M.A.
Thomson, Joseph John, M.A.
Tidy, Charles Meymott, M.B.
Tonge, Morris, M.D.
Topley, William, F.G.S.
Tribe, Alfred, F.C.S.
Vivian, Sir H. Hussey, Bart.
Warren, Sir Charles, C.M.G., Lieutenant-Colonel R.E.
Warrington, Robert, F.C.S.
Watson, Professor Morrison, M.D.

The following Papers were read :—

I. "Magnetic Polarity and Neutrality." By Professor D. E. Hughes, F.R.S. Received February 23, 1884.

In recent papers upon the Theory of Magnetism,* I gave the opinion drawn from a long series of personal researches, that magnetism in iron and steel is entirely due to the inherent polarity of its molecules, the force of which could neither be destroyed nor augmented; that, when we have evident magnetism, the molecules rotate so as to have all their similar polarities in one direction; and that neutrality is a symmetrical arrangement or a balancing of polar forces, as in a closed circuit of mutual attractions. The series of researches which I now present bear unmistakable testimony to the truth of these views, showing the opposite polarities which exist in an apparently neutral bar of iron; and that it is by this means alone that external neutrality occurs in the iron cores of an electro-magnet upon the cessation of the inducing current.

The instrument used for measurements† consists of a delicate silk fibre-suspended magnetic needle, always brought to its zero-mark by the influence of a large magnet at a distance, the angle of which gives the degree of force required to balance any magnetised body placed on the opposite side of the needle. It can also employ electro-magnetic effects by the use of two opposing coils on each side of the needle, balanced so that an electric current passing through the coils has no influence on the needle, except when a piece of iron or steel is placed inside one of the coils; this again being balanced and measured by the large revolving magnet.

* "Proc. Roy. Soc." (vol. 35, p. 178), and "Journal of the Society of Telegraph Engineers," vol. xii, 1883.

† "On a Magnetic Balance, and Researches made therewith," by Professor D. E. Hughes, "Proc. Roy. Soc." (vol. 36, p. 167).

Before commencing my researches upon neutrality, I felt that it was necessary to observe the curves of magnetic penetration, whilst under the influence of its inducing cause. It is well known, however, from the researches of Gaugain, Du Moncel, and Jamin, that the magnetism does not penetrate to a very great depth with its full force, decreasing rapidly from the exterior to the interior. Most observations have been made by means of tubes of various thickness, introduced into each other. These, however, introduce an element of error, as, in separating them, they are necessarily drawn over each other. Jamin's method of dissolving the exterior of a steel magnet in diluted sulphuric acid gave results free from experimental error, but this could only be employed after the cessation of the inducing cause; the observations being really upon the permanent remaining magnetism.

The methods employed by myself consisted, first, in superposing twenty flat iron strips, $\frac{1}{2}$ millim. thick, 20 centims. long, and 3 centims. in width. These could be built up into a solid rod 1 centim. total thickness. Each piece was carefully selected and measured for its magnetic capacity, so that they should all be equal in value whilst under the influence of an inducing force, as well as their remaining magnetism when the influence ceased; the remaining magnetism being about $\frac{1}{4}$ of its capacity in the size and kind of iron employed.

These strips forming a compound bar were placed in contact with the poles of a strong permanent magnet, or they could be laid on one pole, the object being to polarise the lower bar only by contact, and observe the degree of penetration. The upper strip was carefully separated whilst the remainder was left under the polarising influence. We could thus separate each bar while under the influence without fear of reactions taking place between the separated bar and its companions. We had thus a bar or strip, separated while under the inducing influence, and, knowing its coefficient of remaining magnetism, we could estimate its full power when under the polarising influence. By this means the values were plotted graphically, giving curves of varying degrees, as the inducing force was changed, or the material of the strip from soft iron to hard steel. These curves were verified by a somewhat similar method, using a separate strip whose coefficient of remaining magnetism was known, and drawing this over the poles of a magnet, but separated from it by different degrees of thickness of iron.

These again were verified by an electro-magnetic method, in which a series of concentric tubes divided lengthwise was employed, so as to allow separation without friction, confirming the numerous curves obtained by the previous methods, showing that with a limited magnetising power acting upon homogeneous iron or steel, the penetration is inversely as the square of the distance from the inducing power, but

with high powers the exterior soon arrives at its saturation, the distant layers rise in value, and also if the bar is not homogeneous there is a consequent deformation, owing to the comparative rigidity of its molecules.

In all cases, whatever the force employed, or nature of the iron or steel, there are no reversals of polarity in the interior, but a constant diminishing curve of penetration from the outside to the centre. This changes, however, the instant the exterior polarising force ceases, the different degrees of force between the external and internal react upon each other, producing the following results :—

Internal Waves of Opposite Polarity.

All varieties of iron and steel have a high magnetic capacity whilst under the influence of its inducing force, such as the electro-magnetic coils, or strong permanent magnets, but this power in a great measure disappears on the cessation of the inducing influence, a return more or less perfect towards neutrality being the result; remaining magnetism is therefore a partial neutrality, more perfect in soft iron, where the molecules are in a greater state of freedom, than in comparatively rigid cast steel. Our so-called permanent magnets are simply the remains of a far higher magnetic state, and it is already in most cases half-way down on its road to neutrality.

It is absolutely necessary in a theory of magnetism that we should know the cause of neutrality, for it is really the starting point to appreciate how polarity becomes evident. In my previous researches upon neutrality I used the induction balance, but in these I have employed more simple methods, which allow of repetition by the most simple means.

The first consists in forming compound bars of ordinary hoop-iron, $\frac{1}{2}$ millim. thick, and 30 or more centims. long, twenty or more of which could be superposed, bound together by a fine copper wire and forming a rod of any desired thickness; they were magnetised by drawing over magnets of various powers, and the degree of approach to neutrality observed by the amount of its remaining magnetism. Now, on carefully separating them, there were invariably found violent curves of opposing magnetism, previously held bound by the closed circuit of mutual attractions.

The second method consists in superposing the divided concentric tubes, already mentioned, bound together by a fine copper wire, and magnetising them in the electro-magnetic coils of the measuring balance; by this means we could observe the charge or full magnetic capacity under the influence of an electric current, the remaining magnetism upon its cessation, and after taking out the tubular core, separate it, and observe the polarity of its successive internal layers. This method is objectionable, as the slightest rubbing of one tubular

surface against another may alter the true value. The electro-magnetic method is however infinitely superior when observations are made on solid bars, or tubes of different degrees of thickness, to observe the influence of depth or thickness, in producing a perfect return to neutrality after cessation of the inducing effect of the coils.

The third method was a chemical one, somewhat similar to that employed by Jamin, except that as the object was to study the curves of neutrality, the bars were of annealed steel, highly magnetised in the coils, and afterwards reduced almost to a zero, by vibrating them, or beating them gently with a wooden mallet. We had by this means aided the molecules to follow their inclination, as they do in soft iron, for when a soft steel rod is in a state of vibration, its molecules are comparatively free; but they rigidly retain the true curve of neutrality when not vibrated. We are thus enabled by dissolving the exterior in various dilute acids, and by taking repeated observations, to draw graphically the waves of opposing polarities, which have produced external neutrality.

The curves obtained by the different methods are identical in form. The simplest and most accurate method is the first, as we can choose a hard variety of iron, such as ordinary hoop-iron, and by slight vibrations, or blows with a mallet, allow the molecules sufficient freedom to form their curve before separating, and as the material is sufficiently rigid not to be influenced by mere contact, or even frictional drawings, we have on each strip a perfect record of its state, and can thus analyse the internal state of a neutral compound bar.

If we take a compound bar of the hoop-iron, and draw the lower side over the south pole of a magnet, it will be found nearly neutral, or if not sufficiently so, we can reduce it by slight blows with a mallet: suppose the united bar gives still a remaining magnetism of 18° on the magnetic balance, on separating the components and observing the same ends we find the lowest (or the bar which had touched the magnet) 150° north polarity, the next may be slightly north or zero; the rest will have varying degrees of south polarity, from 60° to 10°, the total of which exactly balances the north polarity of 150, less 18°, which we already observed as the remaining magnetism.

If we do not wish to approach a perfect neutrality, we should not vibrate the rods. In this case we may have 75° of remaining magnetism, and find on separating the strips, that we have on lower strip 150° north, and the total opposing south polarity of the interior but 75° south, leaving the remaining 75° of north polarity first observed on the compound bar unbalanced.

The mutual reactions between the magnetic molecules in a solid bar are precisely similar to those between two or more separate bars,

the reactions in the solid bar being more pronounced and complete than those obtained through a separation of air; the greater the separation the less the reaction, but in no case will the law of neutrality be changed.

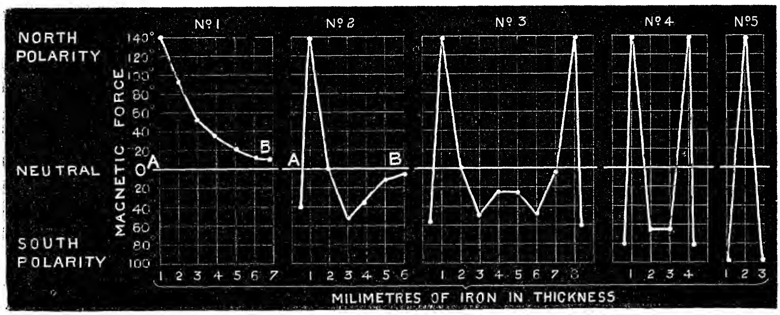
In homogeneous iron or steel, we have a well-defined curve, the distance of which can be calculated from observation upon the remaining magnetism, but if the interior is harder than the exterior, the inner portion will from its rigidity preserve its previous magnetism, reversing entirely the outer portions. This occurs also in small electro-magnets where from the small number of molecules in the interior compared with the vastly greater exterior, and also all the surrounding inducing lines of magnetic force acting on the centre from all sides, the outside is completely reversed to a remarkable depth.

I have been enabled to prove this by the chemical method, employing either dilute sulphuric acid, acidulated bichromate of potass, or dilute nitric acid (1 pint acid to 5 water), the latter being far more rapid and equal in its action. The following experiment will show rapidly the influence of the outside reversal polarity. Let us take a soft steel wire 1 millim. diameter, 10 centims. long. Magnetise it in a coil, or by drawing over a strong permanent magnet, so that it has perhaps a remaining magnetism of 200°. If we vibrate this rod or give several blows from a mallet, we can reduce this to 25°; we have now almost perfect neutrality, having only a remaining magnetism of 25°, which remains a constant for years if not remagnetised. Place this rod in dilute nitric acid, and in fifteen minutes it will rise to 50°, or double its previous value, in one hour to 75°, and two or three hours to 100°, or four times its previous force; the increased force of 75° has been rendered evident by dissolving an equal opposing polarity of 75°, so that we have already found $75+75+25=175°$, or 87 per cent. of its highest force. This is so easily repeated with soft steels of all sizes and dimensions, that there can no longer be any doubt as to the existence of the outside reversed polarity. The experiment is more difficult to repeat with soft iron, as from the freedom of its molecules a fresh outside reversed curve is formed anew as the exterior is dissolved, the balancing curves reproducing themselves until we have almost entirely dissolved the iron; still with care, and iron not too soft, we can render evident all the neutral curves seen in steel.*

The curves obtained by the various methods are so numerous, each requiring more space than the limits of this paper will allow, that I

* Thin flat steel, such as clock-springs, saw-blades, or ribbon steel, well annealed, are most suitable for this experiment. They may be of any width or length; the thickness may vary between $\frac{1}{4}$ and $\frac{3}{4}$ millim. I have found that strips of $\frac{1}{2}$ millim. thick give the highest result.

am forced to give roughly the general outlines, as in fig. 1. Suppose we take a compound bar of iron, of eleven strips, and draw it over a permanent magnet, polarising its lower side only, its neutrality may be found nearly perfect, or 15° of remaining north polarity at the north end; now on carefully separating these rods and observing the same ends, we have for the lower or the side which had been



magnetised, 350° north; the following successively observed would give 10° south, 35° S., 55° S., 60° S., 50° S., 40° S., 22° S., 10° S., 6° S., 5° S.; here all the superposed bars are opposite in polarity to the exterior 350° north, the total south observed being 292, plus 30° south obtained from the exterior, by the coating of its lower face with the $\frac{1}{10}$ milim. of iron strip already mentioned. We are thus enabled to account for 323° degrees south, and 350° north, leaving a remaining magnetism unaccounted for of 12°, which was doubtless disseminated on the surface of each bar on separation.

The above curves were obtained from the same polar (north) end of a compound bar of iron, the south or opposite end of the bar would give reversed curves to these. The curves are reductions to a similar force, but do not exhibit the perfection of the curves obtained on a larger scale.

No. 1 represents the typical curve of penetration of a bar of iron, whilst under the influence of an exterior polarising force, applied at A, or only at one side of a bar. When the force is applied to the whole of the exterior surface (as in a coil), A would represent the polar force on its surface, whilst B the interior. In all cases there would be a depression at the centre; great if the bar is thick, and comparatively small if the bar is thin. The curve rises with the exterior polarisation force, but in no case can a reversal ensue whilst under its influence. The instant, however, that it ceases, the higher magnetic power of the exterior layers reacts gradually and successively upon the weaker interior layers, rotating them through neutrality to a strong opposite polarity.

This is seen in No. 2, which represents exactly what takes place in No. 1 upon the cessation of the inducing influence. We notice that the first portion of the exterior has rotated to south polarity, followed by an intense north, but not of great density; its reaction, being more violent, rapidly rotates all the interior to a south polarity, gradually weakening in intensity as the distance increases from the inducing north polarity. The exterior, in fact, reacts upon its interior precisely as before the inducing exterior magnet reacted upon the whole. In No. 1 the south pole of the permanent magnet produced a continuous curve of north the instant this ceased, the north of the exterior produced an interior south, and if these are perfectly balanced, then and then only will the bar become neutral.

When both sides of a bar are polarised at the same time, then we have two similar curves to No. 2, as shown at No. 3, the diminishing curves of internal opposing polarity overlapping each other; the curve represents those obtained on bars 2 centims. in thickness. If the inducing force is great the penetration is greater and more intense, reacting more violently, and the central depression of the opposing waves is less pronounced. If we keep the previous force and diminish the thickness of the bar, the two central waves cross each other, and at last, as in No. 4, we have only one wave; this occurs with bars of but 3 millims. thickness. We notice here that from a want of sufficient material in the centre of the iron, it is constrained to force its central wave to a far higher degree, and that the exterior now also commences to be reacted upon more violently. Evidently the conditions are strained, and we shall see the result later. This want of sufficient material to form the internal opposing wave of polarity is shown when we reduce the thickness of the bar to 1 millim., the width being 3 centims., and the length 30 or more, as in all previous cases. Here there are no traces of an internal curve, the opposing polarity, as shown in No. 5, being entirely on the surface.

I have shown that we may clearly perceive this curve by dissolving its exterior in dilute nitric acid, but as I employed vibrations to reduce it to neutrality, this might give rise to objections on the score of mechanical reactions. To meet this objection several strips of magnetised steel of various forms, but all $\frac{1}{2}$ millim. in thickness, were reduced almost to neutrality by simply heating them to a dull red heat, allowing them to cool slowly. These gave remarkable results, proving that the vibrations caused by heat are similar in results to mechanical vibrations, and I found that in most cases their external evident magnetism was increased 100 per cent. by an immersion of fifteen minutes, and 600 per cent. in one hour.

Interesting results can be obtained by this method, but if rapidity of chemical action is desired we must first remove the scale or oxide

on the exterior by polishing with emery paper, or dissolve this first in acidulated bichromate of potass.

A perfect curve of these opposing polarities can be obtained by placing a glass vessel containing the steel and solvent in the balance itself, taking continual observations during its solution, and we may thus observe the gradual rise in force to a maximum, then its fall to zero, to an opposing polarity, completely verifying all previous observations.

Supposing the magnetised steel previous to heating gave 200° we should reduce it to 50° if heated to dull red, a bright red heat would probably reduce it to 20°; we should then start from an almost perfect neutrality to find, on dissolving its exterior (and allowing for the reversed polarity of the reversed portion), all its previous polarity.

Faraday remarked that the magnetic qualities of iron disappeared at yellow-red heat (1050° C.), reappearing gradually when cooled to red heat (700° C.). I have found that if we heat the steel to yellow-red heat the whole previous structure disappears, and does not reappear on cooling. No satisfactory explanation, as far as I am aware, has been offered relative to the disappearance of the magnetic qualities of iron and steel at certain temperatures, but noticing that its internal structure is also changed, the following hypothesis may explain the phenomenon.

Assuming that increased heat increases molecular vibration, and that molecules would oscillate to a degree dangerous for the stability of any previous structure, a moment would arrive when the oscillations were so great that all structural formations disappear; and precisely at this instant there would be no external evidence of polarity, or magnetic quality, as the molecules would be oscillating through a range on both sides of external neutrality. On cooling (the previous structure having disappeared) they would satisfy their mutual attractions by the shortest path, forming probably, if perfectly free, a closed circuit of two, grouping themselves as a double molecule; but if a directing influence, such as a continuous current of electricity, was passed through the bar, then they would obey this influence, and in the latter case the closed magnetic circuit would be in concentric circles, as I have demonstrated in previous papers.

A similar effect is caused by mechanical vibrations. I have already shown that we increase the internal curves by gentle blows of a mallet, thus allowing the molecules sufficient freedom to follow their path, as in the case of red heat; but if we strike violently upon the end of the rod, the whole structure is broken down by the violent oscillations of its molecules, and the neutrality now resembles exactly that produced at yellow-red heat.

The theory of symmetrical neutrality which I have demonstrated,

requires that there should be a sufficient thickness in a bar of iron or steel in order to produce a symmetrical opposing polarity. Coulomb's theory of the neutrality taking place in the molecule itself requires no thickness except that of a molecule. Ampère's theory could allow of heterogeneity on the surface as easily as in the interior, consequently thickness of a bar would, according to these theories, have no favourable result; but if the theory that I have advanced is true, thickness should have the greatest possible influence. An extremely thin strip or bar of iron should have an infinitely higher proportionate remaining magnetism from the want of interior reaction, whilst an extremely large solid bar should have infinitely less proportionate remaining magnetism. This at once allows us to test the truth of the theory by an independent method free from all experimental errors, as we may place in the coil of the magnetic balance bars of iron or steel of different degrees of thickness, observe their magnetic capacity whilst under the influence of an electric current, and the degree of remaining magnetism on its cessation, and note the extraordinary influence which thickness has in allowing space for the opposing waves of polarity to produce instantly a higher degree of neutrality than is possible without its aid.

The conditions of the experiments are really those of ordinary electro-magnets, the iron or steel under observation is simply at the time of observation a core of an electro-magnet.

Numerous experiments were made on this subject, all confirming the views advanced. A few examples will be sufficient to include them all, for if we place in the coil of the balance different thicknesses of the same diameter and length of iron or steel, we notice a marked rise in its exterior force or magnetic capacity while under the influence of the electric current, and upon its cessation an equally marked return to a more perfect neutrality with each increase of thickness. The table on the following page contains sufficient examples to show this clearly.

This table gives the results of round cores; experiments, however, were also made with flat bars with like results, the form or length having no direct influence, as the reactions are transversal and localised from a point in the exterior to one in the interior.

Comparing No. 1 of the table (consisting of an extremely thin sheet-iron tube) with No. 2 (a solid bar of iron of exactly similar size), we have for the thin tube a remaining magnetism of 50 per cent. of its previous polar force, and in the solid bar we have only 3 per cent.; whilst in the solid bar, where the opposing waves of polarity could easily form and produce a near approach to neutrality, we find that its polar force under the influence of the coil is 400 per cent. greater than that of the thin tube.

Although, as well known, hard steel has a higher retaining power,

No.				Magnetic capacity under influence of the coil. 1 Daniell element.	Remaining magnetism on cessation of the electric current.
1.	Tube of thin soft iron, 2 centims. diameter, 20 centims. long, $\frac{1}{10}$ millim. thickness			218°	106°
2.	Similar size solid rod of soft iron			960	29
3.	„ „ cast steel, tempered			458	18
4.	„ „ bundle of 1 millim. diameter soft iron wires			1268	142
5.	„ „ glass tube filled with iron filings			160	15
6.	Soft Swedish iron wire, 1 millim. diameter			455	105
7.	Hard tempered cast-steel wire, 1 millim. diameter			49	16
8.	Brass tube	Electro-plated with iron extremely thin	3 centims. diameter 20 „ long	0·95	0·94
9.	„	Electro-plated with iron to $\frac{1}{10}$ millim. thickness	„ „	231	109
10.	„	Ditto, 1 millim. thickness	„ „	401	72
11.	„	„ 1 centim. „	4 centims. diameter	1075	35

still, this can be reduced far below that of the soft thin iron if sufficient thickness is allowed in order to produce the internal reactions. This is shown in No. 3, where a solid 2 centims. diameter of hard-cast steel has double the force of the thin soft iron under polarising influence, and its remaining magnetism only 4 per cent. of its previous force. This shows clearly that Jamin's views of the superiority of thin steel bars over thick where permanent magnetism is desired, are fully confirmed, as in order to have raised the cast-steel 2 centims. thick bar to a high remaining magnetism, we should have had to employ at least fifty times stronger inducing force than that necessary for the thin bars. The proportion of remaining magnetism in iron or steel to the inducing force is almost similar throughout the entire range up to saturation, where the remaining magnetism is no longer proportional to the inducing power, but remains a constant, no matter how high and powerful the influence excited. The molecules have simply then rotated to parallelism and cannot rotate further without diminishing its force, and the sudden spring back to a partial neutrality is then the same for all forces above that of saturation. The proportion of remaining magnetism to that of its magnetic capacity under the influence of an inducing field, is shown in Nos. 6 and 7, where iron and steel wires of similar diameter have not a wide difference, the remaining magnetism here

being 25 per cent. for iron, and 33 per cent. for steel of its proportionate previous force.

The most conclusive experiments, however, will be seen in Nos. 8, 9, 10, and 11. No. 8 being a brass tube coated with an exceedingly thin transparent coat of iron (I was unable to measure its thickness), this thin coating of iron was easily raised to its saturation by a feeble battery, from which point no increase of battery power had the slightest effect, giving always 0°·95. The extraordinary effect of thinness was seen on taking off the inducing influence, no perceptible movement of the needle on the balance occurred, indicating that its retaining power was the same as its capacity or 100 per cent. of retention; vibrations and hammering which reduce a solid bar at once to perfect neutrality had no effect. I have, however, marked it down as 0°·94 as a limit of experimental error; if we assume only 80 per cent. of its previous force it is still sufficiently remarkable. At No. 9 where the brass was coated to a measurable thickness of $\frac{1}{10}$ millim., we already see a better return to neutrality, having now only 50 per cent. of proportionate remaining magnetism; at No. 10, where we have 1 millim. thickness, we have improved our neutrality by having only 20 per cent., and at No. 11 we have, by means of an increased thickness of 1 centim., almost completely allowed the balancing waves of opposite polarity perfect formation, the remaining magnetism now being only 3 per cent. of its proportional power; and if we even neglect the proportional power, we see that the 1 centim. bar has far less remaining magnetism than that of 1 or $\frac{1}{10}$ millim., whilst its magnetic capacity is far higher.

No. 4 shows that while bundles of wires have a higher remaining magnetism than solid (due to the want of homogeneity allowing perfect formation of the opposing waves), still from their increased surface exposed to the inducing effect they give a higher magnetic effect, the differential effect (as that employed in temporary electro-magnetic and induction coils) is greater, being here for a solid bar $960-29=931$, and for the bundles of iron wire $1,268-142=1,126$ useful effect.*

The effect of thickness even upon finely divided iron such as filings is shown in No. 5, where the remaining magnetism is only 9 per cent. against 50 per cent. as shown in No. 1, and we have precisely similar

* If we require a continuous magnetic effect, as in the field magnets of dynamo machines or small constant electro-magnets for extremely feeble electromotive force, solid cores or bundles of wire of large diameter should be employed, but as the time of charge and discharge increases with the diameter, it would be unsuitable for electro-magnets requiring rapid charges, such as those employed for telegraph relays, large electro-magnets requiring several seconds to charge them to saturation, while extremely small electro-magnets may be saturated in the $\frac{1}{1000}$ part of a second.

results with thin slices of iron filings as we do with the solid iron in sheets or tubes.

It would be difficult to explain these effects upon any hypothesis except that of molecular rotation. For, if we regard it as simply a case of magnetic induction, the stronger reacting upon the weaker, we fail to explain the perfect spiral form of the opposing waves, and above all, the reversal of the exterior, which was evidently the most strongly polarised, but if we suppose that the similar polarities of all the molecules have rotated, symmetrically pointing their north polarities to the evident north end of the bar, we have only to imagine a series of magnetic needles superposed with all their north polarities pointing in one direction brought and held there by the influence of a strong external magnet. If this influence was nearer the first needle than the last, we should have a slight spiral due to its diminishing effect, precisely as we notice in the curve in iron whilst under external influence. Now withdraw the exterior force, the needles would react against each other, and as they are free to move in all directions, there would be an increased spiral, the outside being reversed to its previous position, while the spiral would continue in the interior, reversing the larger portion of the needles until they all found a position of equilibrium, which would then represent neutrality.

If we had no frictional resistance to molecular rotation, we should obtain perfectly balanced curves in comparatively thin iron, but as this resistance is great and demonstrated by the loosening influence of mechanical vibrations, we require a certain depth of iron so that a complete curve shall be easily obtained with comparatively infinitely small motion of each molecule.

That inherent magnetic polarity is a quality of all matter, solid, liquid, gaseous, and the ether itself, varying only in degree and not in nature, seems demonstrated by a series of researches I have been making upon the mechanism employed in magnetic conduction through the atmosphere and Crookes's vacuum.

These researches are being made by means of the induction and magnetic balance. They prove that the atmosphere, and presumably the ether as well as all liquids and gases, have their saturation point similar to iron, that the curve is the same as in perfect soft iron, and that the highest magnetic capacity of iron does not exceed that of the atmosphere by more than forty times, consequently we may fairly assume that the ether may be regarded as an extremely magnetic body, obeying the same laws as those of iron; and as I regard the symmetrical rotation of magnetic molecules as the cause of evident magnetism in iron, and as the difference in force between iron, copper, and ether is simply a differential one, I believe that the neutrality which appears in all paramagnetic and diamagnetic bodies, wherever

the exciting influence is withdrawn, is formed by mutual molecular reactions producing closed circuits of mutual attractions as demonstrated in iron.

A line of force between a magnet and its armature is to me simply a line of molecular rotation, lines would neither be added nor subtracted, they could simply be rotated from a symmetrical neutrality to an equal symmetrical point of saturation.

In my paper upon the theory of magnetism, I showed that there were several molecular arrangements which produced external neutrality, the circular chain of molecules, when an electric current passes through an iron wire, a neutrality produced by an artificial superposition of a weaker contrary magnetism upon one more internal, and made the supposition that were it possible to have a piece of iron free from the influence of the earth, then (if there had been no previous magnetisation directing the structure) the molecules would short circuit their mutual attractions in the shortest path.

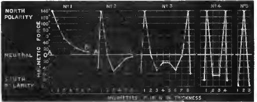
The experiments cited in this paper are of an extremely simple nature, and after being verified by independent observers can no longer leave doubt as to the cause of neutrality.

Whatever theory we adopt as an explanation of evident magnetism, it will be found that neutrality occurring after the cessation of an external inducing force upon a bar of iron or steel, is the result of symmetrically opposed polar forces, producing apparent waves of opposite polarity, or reactions between the exterior and interior of a bar of iron.

II. "On the Origin of the Fibrin Ferment." By L. C. Wooldridge, M.B., D.Sc., George Henry Lewes Student. Communicated by Professor M. Foster, Sec. R.S. Received February 26, 1884.

The "fibrin ferment" which makes its appearance in shed blood is generally, I believe, supposed to arise from the cellular elements of blood, either from ordinary white corpuscles or from some special kind of corpuscles, the cells so concerned discharging the ferment into the blood or setting it free by their actual disintegration. Without wishing to deny that this may be one source of fibrin ferment, I am able, I think, to bring forward evidence that ferment may make its appearance in blood-plasma perfectly free from cellular, and indeed from all formed elements, in which case it must arise from some constituents of the plasma itself, and not from cells of any kind.

It will be most convenient, perhaps, if I state the facts which I have to bring forward in connexion with two series of experiments.



NORTH POLARITY
NEUTRAL
MAGNETIC FORCE
140°
120°
100°
80°
40°
20°
0
20°
No 1
No 2
No 3
No 4
No 5
1 2 3 4 5 6 7 8
1 2 3 4
1 2 3